4.4 GEOLOGY AND SOILS

This section describes the physiography, geology, and seismicity in the vicinity of the Project. The discussion analyzes potential impacts due to ground shaking, soil liquefaction, ground cracking, landslides, subsidence, and flooding. The section also considers potential impacts on soil, mineral, and paleontological resources.

4.4.1 Environmental Setting

Physiography

EPNG Line 1903 lies within the following three physiographic provinces of California and Arizona: the Central Valley (MP 0 to MP 22.5: San Joaquin Valley), Sierra Nevada Mountains (MP 22.5 to MP 50: Tehachapi Range), and Mojave Desert (MP 50 to MP 303.5) (Norris and Webb 1990). Elevations in the Project area range from 270 feet National Geodetic Vertical Datum (NGVD) at MP 303 in the Colorado River alluvial plain (referred to as the Palo Verde Valley) to over 4,000 feet NGVD in the Tehachapi Mountains. The topography in the valley areas traversed by the pipeline consists of low relief in the Mojave Desert and Central Valley, and steep, rugged terrain in the Tehachapi Range.

Geologic Formations

Line 1903 crosses unconsolidated sedimentary deposits, consolidated sedimentary rocks, volcanic and granitic igneous rocks, and metamorphic rocks. The pipeline crosses Tertiary and Quaternary sedimentary deposits in the San Joaquin Valley (MP 0 to MP 22.5). In the Tehachapi Mountains (MP 22.5 to MP 50), the pipeline crosses bedrock largely consisting of Cretaceous age plutonic igneous and metamorphic rocks and sediments derived from this bedrock (Dibblee and Louke 1970, Dibblee and Warne 1970, Ross 1989). The pipeline also crosses valley-fill and alluvial deposits in the Cummings Valley and the Tehachapi Valley within this physiographic province. The pipeline crosses Quaternary and Holocene (the past 10,000 to 12,000 years before present) valley fill, alluvial fan, alluvial deposits, and windblown sand in the Mojave Desert (MP 50 to MP 303.5)—with isolated areas of Mesozoic age plutonic igneous rocks between Mojave and Barstow (Dibblee 1966, 1967; Dibblee and Bassett 1966a,b; Bedinger et al. 1989), the northern edge of the recent Pisgah lava flow between MP 151 to 160 (Dibblee and Basssett 1966b), and a recent lava flow from Amboy Crater between MP 196 to 197 (Bishop 1963).

Geologic Structure

The dominant structural features in the Project area are the Garlock Fault, San Andreas Fault, and a series of faults known as the Eastern California Shear Zone (ECSZ) SCEDC 2000). The Garlock Fault and San Andreas Fault form the western edge of the Mojave Desert (Mojave Block). The San Andreas Fault is a northwest- to southeast-trending high-angle right-lateral strike-slip fault (SCEDC 2000). The Garlock Fault is a northeast- to east-trending left-lateral strike-slip fault (SCEDC 2000). The two faults intersect at the western edge of the Antelope Valley about 17 miles south-southeast of Wheeler Ridge. The ECSZ is a series of northwest- to southeast-trending right-lateral strike-slip faults that cross the Mojave Block east of the San Andreas Fault (SCEDC 2000). The pipeline crosses Calico, Pisgah, and Ludlow Faults of the ECSZ (Dibblee 1966, 1967; Dibblee and Bassett 1966a,b). These faults exhibit evidence of Holocene (recent) rupture with the exception of the Ludlow Fault, which is not identified as active (SCEDC 2000).

Seismicity

The Project is located in an area with medium to high seismic hazard exposure (Figure 4.4-1). The Project lies within zones rated 2B, 3, and 4 by the Uniform Building Code (International Conference of Building Officials 1991), with 4 being the highest hazard rank. Buried pipelines can be susceptible to two major types of seismic hazards: permanent ground deformation and wave propagation hazards (O'Rourke and Liu 1999). Permanent ground deformation hazards include displacement of ground across a fault, soil liquefaction, and landslides. Wave propagation hazards result from the ground waves that are set in motion from an earthquake event; these waves may cause stress on the pipeline that may cause rupture.

Faults

The ROW resource maps (in Appendix A) depict the faults crossed by the pipeline. The potential for permanent displacement of the ground surface across active faults is the principal hazard in seismically active areas (McDonough 1995). Severe ground displacement can cause bending or rupture of the pipeline. The Project crosses several fault areas, some defined by the California Geologic Survey (CGS) as earthquake fault zones (EFZs).

The CGS has mapped active fault areas in compliance with the Alquist-Priolo Earthquake Fault Zoning Act (Hart and Bryant 1997). The Project crosses five state-defined EFZs: Garlock Fault, South Lockhart Fault, Calico Fault, Pisgah Fault, and a possible northern extension of the Lavic Lake Fault (CDMG 1976, 1995a, 1995b, and 1988). The Project also crosses other faulted areas that have segments with evidence of surface rupture during the Holocene but that have not been classified as EFZs by CGS. Ross (1989) has also indicated faults in the Tejon Hills Oil Field area (west of the Tehachapi Range) crossed by the pipeline. Table 4.4-1 summarizes faults and fault zones crossed by the pipeline. The faults were identified in the Seismic Hazards Evaluation and Mitigation Plan (SHEMP) prepared by Earth Consultants International (ECI 2002) for this Project. Table 4.4-2 shows the proposed locations of valves with respect to EFZs or other faults mapped by CGS. The major faults crossed by the Project are discussed below.

Table 4.4-1. Summary of Seismic Hazards Evaluation

Approximate Milepost	Hazard	Probability of Occurrence (Additional Comments)
4.25–6.75	Fault rupture–White Wolf Fault	Low (fault ruptured in 1952; large earthquake; not likely to rupture again during life of Project).
16.00–18.00	Fault rupture–Springs Fault	Moderate (fault apparently last broke in the Quaternary—may be near end of strain accumulation cycle).
14.75–17.00	Landslide potential	Low to moderate fanglomerates of the Chanac Formation (Morton and Troxel 1962).
21.50–22.50	Fault rupture–Tejon Canyon Fault	Low to moderate (fault shows no evidence of Quaternary rupture but has geomorphic expression—may be near end of strain accumulation).
22.00–25.00	Landslide potential	Low (granitic rocks).
33.00–34.25	Fault rupture–unnamed fault	Low (fault does not show evidence of Quaternary rupture; has some geomorphic expression).
32.00–33.25 & 34.00–37.00	Liquefaction potential	Moderate (area underlain by alluvial sediments; depth to groundwater unknown but could be shallow based on surface streams and springs in the area).

Approximate Milepost	Hazard	Probability of Occurrence (Additional Comments)
31.25–32.00 & 34.00–37.00	Landslide potential	Low at 31.25–32.00 (granitic rocks). Moderate to high at 34.00–37.00 (metasedimentary rocks).
44.00–45.00	Fault rupture–Garlock Fault	High (fault reportedly last ruptured in this area in 1050 AD—may be near end of its strain accumulation cycle).
43.00–45.25 & 45.50–47.50	Landslide potential	Moderate (granitic rocks and nonmarine sediments including sandstone, shale, and conglomerate. Bedrock near fault zone inferred to be weak and more likely to fail).
73.50–74.00	Fault rupture–Muroc Fault	Low to none (fault does not show evidence of Quaternary rupture and has no geomorphic expression).
±80.00	Fault rupture–Spring Canyon Fault	Low to moderate (fault does not show evidence of Holocene rupture; mapped end of fault does not cross pipeline).
±87.50	Fault rupture–Kramer Hills Fault	Low to moderate (fault does not show evidence of Holocene rupture; mapped end of fault just short of crossing pipeline).
93.00–93.50	Fault rupture–unnamed fault associated with South Lockhart	Moderate (South Lockhart Fault may be near end of its strain accumulation cycle; this secondary fault may rupture co-seismically with the South Lockhart).
96.75–100.00	Fault rupture–South Lockhart Fault	Moderate to high (this section shows no evidence of Holocene rupture—may be near end of its strain accumulation cycle).
113.75–115.00	Fault rupture–North Lockhart Fault	Moderate to high (this section shows no evidence of Holocene rupture—may be near end of its strain accumulation cycle).
115.00–126.50	Liquefaction potential	High (area underlain by shallow groundwater and loose, sandy sediments. Several seismic sources nearby can produce necessary strong ground motions).
118B–118.5B	Fault rupture–Mt. General Fault	Moderate to high (fault shows evidence of rupture in the Holocene—may be near end of its strain accumulation cycle).
±126.00	Fault rupture–Harper Lake Fault	Moderate (this fault section shows no evidence of Holocene rupture; mapped fault ends north of pipeline, but rupture could extend southward across pipeline).

Approximate Milepost	Hazard	Probability of Occurrence (Additional Comments)
125.00–126.00	Landslide potential	Moderate to high (southwest-dipping metamorphic rocks consisting of hornblende, gneiss, limestone, and mica schist).
141.50–145.00	Fault rupture–Calico Fault	High (fault shows evidence of Holecene rupture; fastest slip of all the East California Shear Zone faults).
153.00–154.00	Fault rupture–Pisgah Fault	Moderate to high (fault shows evidence of Holocene rupture—may be near end of its strain accumulation cycle).
157.50–158.50	Fault rupture–Lavic Lake Fault	Low (fault broke in 1999; pipeline crosses the north end of fault; only centimeters of displacement have been measured in this area).
171.00–17.00	Fault rupture–unnamed fault east of Ludlow Fault	Low to none (fault does not show evidence of Holocene rupture and has no geomorphic expression).
169.75–17.00	Landslide potential	Moderate (knob north of pipeline consists of southwest-dipping beds of tuff breccia).
178.50–179.25	Fault rupture–Ludlow Fault	Moderate (fault shows evidence of Holocene rupture in sections away from the pipeline and has geomorphic expression).
273.00–275.00	Landslide potential	Moderate (a landslide complex has been mapped in this area, in foliated metamorphic and granitic bedrock).
294.75–296.00 & 296.75-297.75	Fault rupture–unnamed fault north of Blythe	Low to none (fault does not show evidence of Quaternary rupture and has no geomorphic expression).
293.00–303.50	Liquefaction potential	Moderate to high (area underlain by shallow groundwater and loose, sandy sediments. Seismic sources in Arizona can produce necessary strong ground motions).

Source: ECI 2002.

Table 4.4-2. Proposed Valve Locations with Respect to EFZs and Other Faults

Approximate Milepost	Fault	Nearest Downstream Valve (Valve #–MP)	Nearest Upstream Valve	Distance Between Valves (miles)
4.25–6.75	White Wolf	#20–17.56	#21–2.10	15.46
44.00–45.00	Garlock	#18–50.46	#19–32.30	18.16
96.75–100.00*	South Lockhart	#14–116.95	#16–82.70	34.25
113.75–115.00	North Lockhart- Lenwood	#14–116.95	#15–98.70	18.25
118.00B–118.50B	Mt. General	#12, 13–132.10	#14–116.95	15.15
126.00	Harper Lake	#12, 13–132.10	#14–116.95	15.15
141.50–145.00	Calico Fault Zone	#10–156.57	#11–136.57	20.00
153.00	Pisgah	#10–156.57	#11–136.57	20.00
157.50-158.50	Lavic Lake	#9–176.57	#10–156.57	20.00
178.50-179.25	Ludlow	#8–196.57	#9–176.57	20.00
294.00-297.75	Unnamed	#1–303.50	#2–286.30	17.20

Proposed Valve #15 (MP 98.70) lies within the milepost range of the South Lockhart Fault crossing.

The Garlock Fault, which bounds the northwest and north sides of the Mojave Block, is 150 miles long and has caused up to 11 miles of left-lateral strike-slip displacement since the Quaternary, and 250 feet of displacement in the Holocene. Although no historical earthquakes have caused surface rupture on the fault, the fault is considered active because of movement during the Holocene (SCEDC 2000). The most recent large earthquake on the Garlock Fault Zone was a 5.7-magnitude quake that occurred in July 1992 near Mojave, California. In 1952, an earthquake on the nearby White Wolf Fault resulted in observed surface cracks in a location along the Garlock Fault. The cracks were 400 feet long, but there was no observed displacement (Dibblee and Louke 1970, Buwalda and St. Amand 1955). In 1952, the cracks along the Garlock Fault were observed where Oak Creek Road crosses the fault, about 2,000 feet southwest of where the Project crosses the fault. The last major ruptures on the fault are thought to have occurred in the Project area in 1050 AD and in about 1500 AD in the Searles Valley, northeast of the Project area (SCEDC 2000).

The White Wolf Fault parallels the Garlock Fault to the northwest and is located in the extreme southeast portion of the San Joaquin Valley. The fault is a left-lateral reverse fault that dips to the southeast (SCEDC 2000). It is about 40 miles long and trends southwest to northeast from Wheeler Ridge to Caliente, California. The trace of the fault is inferred in the Central Valley sediments but is well defined along the west edge of the Tehachapi Range (Ross 1989). The most recent rupture on the fault occurred in the 1952 earthquake that is referred to as the Kern County or Arvin-Tehachapi Earthquake. The epicenter of the quake occurred at Wheeler Ridge, 3.5 miles due south of where the Project crosses Interstate 5 (SCEDC 2000). The 1952 earthquake on the White Wolf Fault was the largest earthquake in California (magnitude 7.5) since the 1857 Fort Tejon Earthquake. Prior to the 1952 earthquake, the White Wolf Fault was not recognized as active (Hill 1955).

There is no surface expression of the White Wolf Fault at the pipeline crossing; its presence in this area is indicated by subsurface data (Buwalda and St. Amand 1955). Although no rupture was described in this area in CGS Bulletin 171 (Oakeshott 1955), the 1952 earthquake affected roads and bridges in the vicinity of Wheeler Ridge (Perry 1955).

East of the San Andreas Fault are parallel sets of northwest-southeast trending faults that cross the Mojave Block. These primarily right-lateral strike-slip faults of the ECSZ that cross the Project include the North Lockhart Fault, South Lockhart Fault, Lenwood Fault, Mt. General Fault, and the Harper Lake Fault. The North and South Lockhart, Lenwood, and Mt. General Faults exhibit evidence of Holocene rupture. The other faults show evidence of Quaternary surface rupture.

The Calico and Pisgah Faults exhibited triggered slip from the June 1992 Landers Earthquake at 7.1 magnitude (SCEDC 2000). The epicenter was located 30 miles south of MP 158 and caused up to several feet of movement on nearby faults, with minor rupture or triggered slip on other faults such as the Calico and Pisgah. Triggered slip probably results from ground shaking from an earthquake on another fault (SCEDC 2000).

Several other faults are in the Project vicinity but are not crossed. The Spring Canyon and Kramer Hills Faults are located south of Kramer and terminate a few miles south of the ROW (Hart et al. 1987, ECI 2002). It is possible that these faults actually extend beyond the end points on the map by Hart et al. (1987), but there is no surface expression to justify extending the faults further.

The Project also crosses mapped faults that are not classified as active faults and are not listed in a CGS assessment of Mojave Desert faults (Hart et al. 1987). An unnamed fault mapped by Dibblee and Bassett (1966b) is crossed by the Project at MP 157.25, but the fault trace is mapped as indefinite because there was not enough evidence to accurately locate the fault. This fault is 1.0 mile west of the fault zone described above as a possible northern extension of the Lavic Lake Fault. The Project crosses a northwest- to southeast-trending unnamed fault twice between MP 294 and MP 297 (Jennings 1967).

The lack of seismic activity or discernable movement on a particular fault does not preclude the potential for rupture to occur, as was discussed for the White Wolf Fault. A recent example is the Lavic Lake Fault that is 47 miles east-southeast of Barstow that had not exhibited evidence of Holocene movement until 1999. However, this fault showed significant movement as a result of the 7.1-magnitude Hector Mine Earthquake that occurred in October 1999 (USGS 2000). The surface rupture was almost 30 miles long and had a maximum displacement of 17 feet. The Lavic Lake Fault is a branch of the Bullion Fault and may actually extend as far north as the Project route. Prior to the Hector Mine earthquake, the fault was not classified as active because there was no evidence of movement during the Holocene. The Project crosses what may be the north extension of the Lavic Lake Fault at the EFZ located between MP 157.5 and MP 158.5. The epicenter of the Hector Mine Earthquake was about 14 miles south-southeast of MP 158. The EFZ at MP 158 was previously not identified as associated with the Lavic Lake Fault, but the surface rupture from the Hector Mine earthquake ends a few miles south of the Project and is in line with the EFZ (USGS 2000). The latest seismic activity in the Lavic Lake area consists of several small (magnitude 2–3) earthquakes recorded in early February 2001 (SCEDC 2001). The epicenters lie in a northwest to southeast line from north of Interstate 40 to southeast of Lavic Lake.

Volcanism

The pipeline crosses a young lava flow fields (6,000 years to approximately 2,000 years before present) from the Pisgah Crater near MP 155 and Amboy Crater near MP 197 (Norris and Webb 1990, Rogers 1967).

Soils

Soil types were reviewed using NRCS Geographic Information System-based STATSGO and SSURGO soil data compiled from photo-based county soil surveys, along with published soil surveys for Kern and San Bernardino Counties. At this time, a published soil survey does not exist for Riverside County. Soil limitations as they apply to pipeline conversion and operation are discussed in the Impact Analysis and Mitigation section.

The primary soil restrictions encountered by the pipeline are as follows: high salinity-alkalinity subsoils that limit revegetation; erosion and soil-blowing hazards; coarse-textured surface layers; steep slopes; shallow depth to bedrock; and susceptibility to flooding. Sensitive soils in San Bernardino County are typically sandy alluvial soils located on or derived from floodplains and terraces of the Mojave River. The sensitive soils in Kern County are typically sandy alluvial soils with moderate to high erosion hazard potential from both wind and water. As previously noted, detailed soil survey coverage does not currently exist for Riverside County (coverage ends at approximately MP 149); however, soil limitations are expected to be similar to those described for San Bernardino and Kern Counties.

Mineral Resources

The major mineral resources in the Project area include oil and natural gas, industrial minerals, base metal, and precious metal ores (Dibblee 1966, 1967; Dibblee and Bassett 1966a, b; Bedinger et al. 1989). The Project crosses oil-producing areas in the Central Valley, and the Tejon Hills oil field between approximately MP 15 to MP 16.5 (California Division of Oil, Gas, and Geothermal Resources 2000). Mineral resources of the Tehachapi Range include gold, tungsten, uranium, and limestone (Dibblee and Louke 1970). One of the primary mineral resources in the western Mojave Desert is borate minerals (Dibblee 1967). Other mineral resources in the Mojave Desert include sand and gravel, gold, silver, copper, barite, bentonite, gypsum, and halite.

Paleontological Resources

Paleontological monitoring and recovery was conducted during installation of the All American Pipeline in 1988 (Reynolds 1988). The records search identified 28 areas on Federal lands with a high or undetermined potential for containing paleontologic resources. These areas were subsequently surveyed, and nine of the areas were determined to have a high probability for the occurrence of paleontological resources. Table 4.4-3 summarizes these areas. Subsequent monitoring during pipeline construction confirmed the fossiliferous nature of the deposits at these nine areas (Reynolds 1988).

Table 4.4-3. Areas of Known Paleotological Resources on Federal Lands

Location	Characteristics
Palo Verde Mesa/Blythe	Excellent exposures of fine-grained Pleistocene river sediments on the west side of the Colorado River. Sediments have high potential for containing well-preserved paleontologic resources.
Danby Lake/Ward Valley/Saltmarsh	Pleistocene lacustrine sediments deposited at higher elevations than the existing surface of Danby Lake. Abundant tooth and bone fragments of extinct horse and camel and fossil root casts were located.
Archer/Cadiz Valley	Fossil mammal bone fragments and fossiliferous limestone were located during field survey in lacustrine sediments deposited at elevations higher than present Cadiz Lake.
Ludlow/Argos	Exposures of fine-grained fluviatile and lacustrine sediments were conducive to the perservation of paleontologic resources.
Hector	Extensive exposures of fine-grained playa silts were located at elevations higher than Troy Lake.
Troy Lake	Extensive exposures of Pleistocene lacustrine and fluviatile sediments deposited at elevations higher than the present surface of Troy Lake playa.
Daggett to Calico Fault	Institutional records and previous field surveys and salvage excavations. Paleontologic localities with abundant and diverse vertebrate and invertebrate taxa exist in this area.
Hawes/Halendale Fault	Excellent exposures of playa silts and lacustrine limestones and silts were located during field survey at elevations significantly higher than adjacent deposits such as at Harper Lake.
Rogers Lake	Fossil remains of antelope, horse, and camel occur in fluviatile, playa, and lucustrine sediments at higher elevations than the present Rogers Lake surface.

Consultation with the San Bernardino County Museum indicates a high probability of encountering significant paleontological resources along the Cadiz Lateral.

4.4.2 Regulatory Setting

Federal

The Federal Water Pollution Control Act of 1972 and Clean Water Act of 1977 require that discharge requirements be met, including the discharge of sediment to surface water as a result of erosion. The Soil Conservation Service (SCS) National Engineering Handbook presents standards for planning, design, and construction of soil conservation practices to be implemented during construction projects.

Applicable Federal, local and regional standards have been incorporated into the Applicant's SWPPP (Appendix D3), UECRM Plan (Appendix D1), and Dust Control Plan (Mitigation AIR-1c) for the Project.

State

The Alquist-Priolo Special Studies Zones Act was enacted in 1972 (in 1994 it was renamed the Alquist-Priolo Earthquake Fault Zoning Act [APEFZA]). The primary purpose of the APEFZA is to mitigate the hazard of fault rupture by prohibiting the location of structures for human occupancy across the trace of an active fault (Hart and Bryant 1997). The APEFZA requires that "earthquake fault zones" be delineated by the State of California (that is, by the State Geologist) along faults that are "sufficiently active" and "well defined." These faults show evidence of Holocene surface displacement along one or more of their segments (sufficiently active) and are clearly detectable by a trained geologist as a physical feature at or just below the ground surface (well defined). The boundary of an earthquake fault zone is generally about 500 feet from major active faults, and from 200 to 300 feet from well-defined minor faults. The APEFZA dictates that cities and counties withhold development permits for sites within an earthquake fault zone under their jurisdiction until geologic investigations demonstrate that the sites are not threatened by surface displacements from future faulting (Hart and Bryant 1997).

The Seismic Hazards Mapping Act of 1990 (PRC Section 2690 and following as Division 2, Chapter 7.8), as supported by the Seismic Hazards Mapping Regulations

(CCR Title 14, Division 2, Chapter 8, Article 10), were promulgated for the purpose of protecting public safety from the effects of strong ground shaking, liquefaction, landslides, other ground failures, or other hazards caused by earthquakes. Special Publication 117, Guidelines for Evaluating and Mitigating Seismic Hazards in California (CDC, Division of Mines and Geology 1997), constitutes the guidelines for evaluating seismic hazards other than surface fault rupture, and for recommending mitigation measures as required by PRC Section 2695(a).

PRC Section 5097.5 (Stats. 1965, c. 1136, p. 2792) defines any unauthorized disturbance or removal of fossil sites or remains on public land as a misdemeanor.

Local

In San Bernardino County, development on sand dunes must receive special review for visual, biotic, and safety and engineering considerations.

4.4.3 Significance Criteria

An adverse impact on geologic or mineral resources was considered significant and would require mitigation if:

- construction activities or the siting of facilities would substantially worsen existing unfavorable geologic conditions; or
- the location and design of the pipeline and related facilities in relationship to geologic hazards could result in a rupture or failure of the pipeline or cause damage to related facilities that would present a significant threat to public safety, as supported by historical performance of similarly designed pipelines that experienced geological hazards comparable to those in the Project area.

An adverse impact on paleontology would result if Project construction would result in damage or loss of vertebrate or invertebrate fossils that are considered important by paleontologists and land management agency staff. The significance of paleontological remains can be determined by the types of fossils, the geologic age of the remains, the assemblage association (the unique biological association or organisms), the lithology and age of the rock units, and its rarity or uniqueness. A paleontological resource can be considered to have scientific or educational value if it:

- provides important information on the evolutionary trends among organisms, relating living inhabitants of the earth to extinct organisms;

- provides important information regarding development of biological communities or the interaction between botanical and zoological biota;

- demonstrates unusual or spectacular circumstances in the history of life;

- is in short supply and in danger of being depleted or destroyed by the elements, vandalism, or commercial exploitation and is not found in other geographic locations;

- is recognized as a natural aspect of our national heritage;

- lived prior to the Holocene (~11,000 B.P.); and

- is not associated with an archaeological resource, as defined in Section 3(1) of the Archaeological Resources Protection Act of 1979 (16 USC § 470bb[1]).

A fossil specimen would be significant if it is (1) identifiable, (2) complete, (3) well preserved, (4) age diagnostic, (5) useful in environmental reconstruction, (6) a type or topotypic specimen, (7) a rare taxon, or (8) part of a diverse assemblage.

A paleontological impact would be considered significant and require mitigation if:

- the resource is considered to have scientific or educational value; and

- Project construction or operation would result in damage or loss of vertebrate or invertebrate fossils that are considered important by paleontologists and land management agency staff.

An adverse impact on soils was considered significant and would require mitigation if Project construction or operation would:

- increase erosion rates or reduce soil productivity by compaction or soil mixing to a level that would prevent successful rehabilitation and eventual reestablishment of vegetative cover to the recommended or pre-construction composition and density;

- reduce agricultural productivity for longer than 3 years because of soil mixing, structural damage, or compaction;
- have the potential to be damaged by exposure to soils with moderate to high corrosion ratings, where the pipeline is not protected with appropriate coating and/or cathodic protection; or
- be located in areas with expansive soils that would damage aboveground structures.

4.4.4 Impact Analysis and Mitigation

EPNG has conducted studies regarding seismic hazards, and has incorporated the recommended design changes into the Project Description. These changes include realignment, increased wall thickness, modified trenching techniques, and changed orientation to accommodate increased pipeline displacement. The results of these studies, and their bearing on geological hazards, are described in the following sections.

Seismic Hazards

The pipeline has been inspected by smart pig, and has not been adversely impacted by seismic events in the past. A Geohazard Assessment prepared for EPNG by AMEC Earth & Environmental, Inc. (AMEC 2002) identified two of the faults crossed with a displacement capacity sufficient to compromise the integrity of the Project during a significant seismic event. These are the Garlock and Calico Faults. AMEC’s assessment is based in part on an Analytical Assessment of Seismic Hazards report prepared by D. G. Honegger Consulting (2002). This assessment used finite-element stress and strain analyses for each of the faults identified in the Seismic Hazards Evaluation and Mitigation Plan (ECI 2002). Of the faults crossed, only the Garlock and the Calico Faults exceeded the allowable strain at the design fault displacements (AMEC 2002). An engineering geologist certified in the State of California would observe the construction excavations at these two fault crossings to ensure that the provisions of the AMEC (2002) report are followed.

The seismic wave propagation hazard was addressed by D. G. Honegger Consulting in their report to AMEC. Based on their analyses, the calculated combined axial and bending stresses induced by longitudinal wave propagation and curvature of the ground caused by passing seismic waves are less than 9 kips per square inch (ksi). The grade of steel used for the Project has an allowable stress level of 65 to 70 ksi. It is therefore unlikely that seismic wave propagation would threaten the pressure integrity of the Project pipeline.

EPNG would construct and test Project facilities to meet Federal standards specified in the US Department of Transportation's (DOT) regulations in Title 49 Code of Federal Regulations (CFR) Part 192, *Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards*.

EPNG would design all Project facilities to meet or exceed the latest edition of the Uniform Building Code (UBC), International Building Code (IBC), and recognized industry standards under the direction of certified professional engineers. However, the UBC, IBC, and DOT (Title 49 CFR Part 192) requirements do not necessarily address all seismic design criteria required in California, particularly at fault crossings and liquefaction potential zones.

In California, the CSLC requires the incorporation of current seismological engineering standards such as the *Guidelines for the Design of Buried Steel Pipe* (American Lifeline Alliance), *Guidelines for the Seismic Design of Oil and Gas Pipeline Systems* (American Society of Civil Engineers), and other recognized industry standards for seismic-resistant design at all fault crossings and liquefaction potential zones in California. The CSLC also requires all engineered structures, including pipeline alignment sheets, buildings and other structures, profile drawings wherever necessary, and other appurtenances and associated facilities in California, to be designed, signed, and sealed by California-registered professionals certified to perform such activities in the jurisdiction where the facilities would be located.

In addition, EPNG agreed to the following seismic design conditions:

- orient the pipe at the fault crossing to produce tension in the pipe material in lieu of compression;
- provide a substantial unanchored length of pipe across the fault;

- create ditch geometries (deeper or wider dependent on fault type and orientation) to minimize forces on the pipe;
- place medium dense sandy backfill around the pipe at the fault crossing;
- use heavy-wall pipe at the fault crossing;
- avoid pipe wall-thickness transitions near fault traces;
- use a certified engineering geologist to observe the construction excavation in the vicinity of the fault crossings to verify that the design assumptions are valid and the treatments are centered in the correction locations; and
- equip the mainline valve (MLVs) located upstream and downstream of the faults with actuators.

The potential for seismic-induced damage to the pipe, and of potential seismic impacts for the Cadiz Lateral, are addressed in Impact GEO-1.

Ground Shaking

The energy generated by an earthquake induces seismic waves that cause ground shaking. Surface structures may be more susceptible to ground motion, but buried pipelines are also at risk (Pelmulder 1995). Pipelines that are corroded or weakened may be especially susceptible to damage. The effects of ground motion depend on many factors, the most important being the type of fault on which movement occurs, the magnitude of movement, the type of rock through which earthquake-induced waves travel, and surface conditions in any given area. The smart pig data on the existing pipeline indicates that it has not been adversely affected by ground shaking.

In addition to the potential ground motion generated from a strong seismic event on nearby faults, the Project could be subject to strong motions generated by the San Andreas Fault. Although the Project does not cross the San Andreas Fault, it bounds the southwest side of the Mojave Block and may have had as much as 40 miles of displacement since early Pliocene (Dibblee 1967). The last major earthquake on the San Andreas Fault in the Project vicinity was the Fort Tejon Earthquake in 1857. The Fort Tejon Earthquake was estimated at magnitude 8.0, caused strong ground motions in the southern Central Valley, and caused rupture over 200 miles along the fault (SCEDC 2000). The epicenter of the Fort Tejon Earthquake is estimated to have been near present-day Parkfield, California, about 60 miles northwest of Wheeler Ridge. Earthquakes along the San Andreas Fault have the potential to generate ground motions that could affect Project facilities.

The expected peak ground acceleration decreases from west to east. Project components in the San Joaquin Valley and the Tehachapi Range are potentially subject to the strongest ground motion from a maximum credible earthquake event (CDMG 2000). The peak ground acceleration may be greater than 30 to 60 percent of the acceleration of gravity, with a 10 percent probability of being exceeded in 50 years. The portion of the Project within this area of expected strong ground motion is from MP 2 (Wheeler Ridge) to approximately MP 56 (just south of the town of Mojave). From MP 56 to MP 132 (Daggett) the expected accelerations decrease to 20 to 30 percent of gravity, with a 10 percent probability of being exceeded in 50 years. For Project components from MP 132 to about MP 174, peak ground acceleration may be 20 to 30 percent of the acceleration of gravity, with a 10 percent probability of being exceeded in 50 years. From MP 174 to MP 303.5 (Ehrenberg) the peak ground accelerations expected are from less than 10 percent and up to 20 percent of the acceleration of gravity, with a 10 percent probability of being exceeded in 50 years. The pipeline design accommodates these loadings, and as such the effect is expected to be less than significant.

Soil Liquefaction

Soil liquefaction occurs when ground shaking induced by an earthquake causes soil to lose its ability to support a load (Wills 1996). Soils that are especially susceptible to liquefaction are water-saturated unconsolidated sand. Liquefaction causes the soil to compact and settle. Buried pipelines may become buoyant because they become less dense than the liquefied soil. Surface structures may tilt or sink. Liquefaction on a slope may cause materials to flow downhill. Lateral spreading is another liquefaction hazard in which blocks of competent soil are displaced horizontally over liquefied strata (Pelmulder 1995).

In California, it was thought that coastal areas and areas underlain by fill were most susceptible to liquefaction. However, recent study by the CGS has shown that desert soils also are susceptible under certain conditions. Valleys in the Project area are characterized by internal drainage; during precipitation, water can collect in the lowest parts of the basins. Under these conditions, groundwater may be at or near the surface. Evidence of liquefaction in these basin and range valleys has been found in features formed by lateral spreading (Wills 1996).

To address liquefaction concerns within these desert basins, EPNG drilled soil borings at Blythe, Danby Dry Lake, Amboy/Bristol Dry Lake, Troy Dry Lake, the Mojave River at Nebo, the Mojave River in Barstow, Tehachapi Valley, and Tejon Hills/Mettler (AMEC 2002). Geotechnical samples from these borings were collected and analyzed for their liquefaction potential during saturated conditions. Soil borings were also drilled at the Emidio Pump Station by AMEC (then Moore & Taber) in 1985 and evaluated in a similar manner. Based on geotechnical analyses of the soil samples collected at each of the nine areas where liquefaction hazards were evaluated, AMEC determined that the soils would produce less than 1 foot of subsidence, even if an earthquake were to occur at a time when the sediments were completely water saturated (AMEC 2002). Results of the finite-element strain analysis demonstrated that the Project could tolerate approximately 2.7 feet of both vertical subsidence and traverse displacement. AMEC reports that larger amounts of subsidence could be tolerated without risk to pressure integrity. Therefore, the displacement capacity of the standard-wall pipe to maintain pressure integrity exceeds the expected displacements along tested areas of potential liquefaction.

Ground Cracking

Ground cracking and slumping not associated with liquefaction or active faults can occur as a result of ground motion (Pelmulder 1995). Areas susceptible to ground cracking are not always predictable before an earthquake occurs but can cause severe damage. In the Northridge Earthquake of 1994, movement of a large block caused the rupture of a high-pressure 22-inch gas pipeline and other smaller distribution pipelines. The 1952 Kern County Earthquake initiated numerous ground cracks over a wide area in the southern San Joaquin Valley. CDMG Bulletin 171 (Oakeshott 1955) documents many cracks and ruptures in the southeastern San Joaquin Valley, but the report does not identify any ground cracking in the area of the present-day pipeline.

Landslides

Landslides involve the mass movement of earth materials as a result of steep slopes or other conditions that result in unstable conditions. Landslides can involve different types of earth materials from rock to clay and can be induced by earthquakes or other conditions that weaken the cohesion of material, such as saturation from heavy precipitation (Pelmulder 1995). Large landslides can cause severe damage to pipelines and surface structures as earth materials rapidly move downhill.

EPNG conducted a geohazard assessment to evaluate landslide potential along the route using aerial and ground-based observations made by a senior engineering geologist licensed in California. The study determined that no landslide deposits have been mapped close to the pipeline alignment (AMEC 2002). Observations made during AMEC's study utilizing the 30-m Digital Elevation Model revealed that the steepest part of the alignment was located in the Tehachapi Mountains. Slope angles were found to range from less than 1 to 31 degrees. The steeper portions of the route through the Tehachapis were ground-truthed in June 2002 by AMEC's senior engineering geologist. Based on ground observations, it was determined that no landslide deposits or unstable slope conditions were observed in the Tehachapi Mountains that would pose a hazard to the pipeline. Additionally, no landslide deposits or unstable slope conditions that would pose a hazard were observed at any location along the route to the pipeline (AMEC 2002).

Subsidence

Subsidence of the ground surface can result in damage due to loss of support and the transfer of stresses in the ground to structures and facilities. Subsidence can be caused by several factors, including withdrawal of subsurface fluids and dissolution of subsurface strata.

Land subsidence induced by fluid withdrawal from subsurface strata is a severe problem in the Central Valley. Subsidence occurs when fine-grained sediments undergo compaction because of the removal of interstitial fluids, such as water, oil, and natural gas. Active subsidence in the southern Central Valley is minor (CSLC and BLM 1984) and therefore is not expected to pose a concern for the Project in that area. Subsidence in many Central Valley areas ceased with reduced groundwater withdrawal in response to availability of surface water for irrigation (Bertoldi et al. 1991).

Subsidence is negligible at the north side of Edwards Air Force Base, where the pipeline is located (Blodgett and Williams 1990), although it has been noted elsewhere on the base.

The USGS Water Resources Division is currently conducting research on subsidence in the western Mojave Desert, using space-based synthetic-aperture radar interferometry (InSAR). The USGS overlaid the pipeline route onto their subsidence maps and reported that the alignment is located in an area that has been fairly stable over the period covered by the radar scenes (1993 to 1995 for the Mojave Valley, and 1996 to 1999 for the western part) (AMEC 2002).

A geohazard assessment (AMEC 2002) concluded that the amount of subsidence during a 50-year design life would probably exceed 2.7 feet, the amount of displacement tolerable by the pipe. EPNG would implement the recommendations of the AMEC (2002) report for subsidence, as follows. The maximum subsidence rate anywhere in the western Mojave Desert is 0.3 feet/year. EPNG would, therefore, conduct a reassessment of the subsidence hazards after every nine years of operation. Regions of subsidence that approach five feet would be identified and the local pipeline condition and performance would be evaluated. EPNG would submit a report of its evaluation to the CSLC and appropriate action would be taken based on the CSLC’s findings. In addition, EPNG would check for evidence of subsidence during routine monitoring of operations. Repairs would be made as necessary.

Soil Erosion

Pipeline construction activities such as clearing, grading, trench excavation, backfilling, and movement of construction equipment along the ROW would affect soil resources. Erosion is a continuing, natural process that can be accelerated by human activities. Clearing, grading, and moving equipment on the ROW would remove the protective vegetation cover and expose soils to the effects of wind, rain, and runoff. These effects would accelerate the erosion process and, without adequate protection, could result in discharges of sediment to wetlands and waterbodies and could lower soil fertility. Although all soils are prone to erosion to some degree, factors that would influence the rate of erosion include soil texture and structure, the length and percent of slope, vegetative cover, and rainfall or wind intensity. The most erosion-prone soils are generally bare or sparsely vegetated, non-cohesive, fine textured, and situated on moderate to steep slopes. Soils more resistant to erosion include those that are well vegetated, well structured with adequate percolation rates, and located in nearly level terrain.

Erosion control measures proposed for the Project are described in EPNG's UECRM Plan (Appendix D1). To summarize, the Applicant would install and maintain various erosion control measures during construction of the Project. These measures include temporary slope breaks on slopes and temporary sediment barriers, such as straw bales or silt fences, across the ROW during construction at the base of slopes; adjacent to waterbodies, wetlands, and roadways; and along the edge of the ROW as necessary to prevent sediment from flowing off the ROW. EPNG would install erosion control netting on waterbody banks, very steep slopes, and in drainages that may be susceptible to erosion. To protect topsoil from wind erosion, water or a water-based, non-toxic, organic tackifier would be applied to the topsoil piles in all areas identified as highly susceptible to wind erosion and in all areas where soil conditions warrant.

Reclamation efforts would be implemented to enhance revegetation and address soils with poor revegetation potential. These efforts would include topsoil segregation, recontouring, applying erosion control mulch on slopes, respreading cut vegetation or preserved rock mulch, imprinting the surface of the ROW, installing permanent slope breaks, and seeding with species adaptable to the climate. These measures also would reduce soil loss through wind erosion.

Soil Compaction

Construction equipment operating and traveling on the construction ROW, especially during wet periods and on poorly drained soils, can compact the soil. Soil compaction can also result from the storage of heavy spoil piles on certain types of soil for extended periods of time. Soil compaction destroys soil structure, reduces pore space and the moisture-holding capacity of the soil, and increases runoff potential. If unmitigated, compaction results in soil with a reduced revegetation potential and an increased erosion hazard. The degree of compaction depends on the moisture content and texture of the soil. Wet soils with fine clay textures are the most susceptible to compaction.

Measures to reduce soil compaction are presented in the UECRM Plan (Appendix D1). To summarize, the Applicant would minimize compaction by adjusting construction schedules to avoid compaction-prone areas during short-term weather events. Rutting and compaction would be avoided or minimized by operating heavy equipment on timber mats across minor tributaries, adjacent to wetlands, and other areas as deemed necessary during construction. EPNG's personnel responsible for environmental compliance, in conjunction with the agencies' compliance monitor, would be responsible for assessing the potential for compaction given the soil type, hydrologic conditions, and current and predicted weather events. After construction, EPNG would test disturbed soils for compaction using a cone penetrometer or other appropriate device and comparing with adjacent undisturbed soils. Should compaction occur, soils would be plowed with a paratill, paraplow, or other deep-tillage device to alleviate compaction. Implementation of the UECRM Plan would reduce impacts associated with compaction to less-than-significant levels.

Topsoil Mixing

In addition to erosion and compaction, construction activities such as grading, trenching, and backfilling can cause mixing of soil horizons. Mixing of topsoil with subsoil, particularly in agricultural lands, leaves less productive soils in the root zone, which lowers soil fertility and the ability of disturbed areas to revegetate. Another result of soil mixing and disturbance can be a change in appearance of the surface disturbed soils when viewed in comparison with the adjacent undisturbed soils. The visual contrast would be especially evident in areas where desert varnish is present on rock/desert pavement. In addition, introducing stones or rock fragments to the surface could result from mixing of topsoil and stony subsoil layers; excess rock brought to the surface could adversely affect agricultural land and restoration efforts.

To reduce the mixing of soil horizons on its construction ROW and any other construction location, EPNG would segregate topsoil in accordance with its UECRM Plan (Appendix D1). Topsoil segregation helps preserve the superior chemical and physical properties of the topsoil and protects the native seed sources. Soil crust propagates, which enhance the recovery of biological crust in desert areas, are also preserved during topsoil segregation. At a minimum, the Applicant would segregate topsoil in all annually cultivated or rotated agricultural lands, hay fields, and residential areas. The Applicant would also segregate topsoil in those lands where the landowner requests that it occur. To ensure that all landowners affected by the Project are aware of their right to request topsoil segregation, EPNG sent letters to all landowners along the ROW to determine their desire to have this treatment on their land.

In general, topsoil segregation is accomplished by separating the topsoil from the subsoil during the trenching operation and replacing stockpiled soil in the proper order during backfilling and final grading. In deep soils, the Applicant would segregate at least 12 inches of topsoil. Where shallow soils (with topsoil less than 12 inches deep) or soils with stony subsoil are encountered, the Applicant would make every effort to segregate the entire topsoil layer. The Applicant would segregate topsoil using one of the following methods: from either the full work area (full-ROW method), from the trench and subsoil storage area (trench-plus-spoilside method), or from the trench and working side (trench-plus-working-side method). As specified in the UECRM Plan, the determination of where each topsoil segregation method would be used must be finalized more than 60 days before construction.

Topsoil would be stockpiled separately from subsoil, and the two stockpiles would be replaced in the proper order during backfilling and final grading. To prevent wind erosion on topsoil, the Applicant would apply water and/or a non-toxic, organic tackifier on the segregated topsoil piles to prevent the loss of the materials through wind erosion. Implementation of this measure would be sufficient to lessen the potential impacts associated with wind erosion. Consequently, where topsoil segregation would occur, the topsoil and subsoil would be stockpiled separately along the Project route.

The EI and agency mitigation monitors would be responsible for ensuring contractor compliance with topsoil segregation. Implementing topsoil segregation as described in the UECRM Plan would reduce the impact of soil mixing to a less-than-significant level.

Although blasting would not be used, trenching and ripping of stony or shallow bedrock soils can bring stones or rock fragments to the surface, which could interfere with agricultural practices and hinder restoration of the ROW. In all actively cultivated or rotated cropland and improved pastures, these impacts would be minimized by segregating topsoil and removing (picking) excess rock from the top 12 inches of soil so that the size, density, and distribution of rock on the ROW is similar to adjacent undisturbed areas. On rangelands, the Applicant anticipates that rocks may be disposed of along the ROW by scattering them in a natural pattern, as permitted by the landowner or land management agency. If caliche is found in the subsoil, small pieces would be buried on the ROW with at least 24 inches of cover, while larger pieces of caliche may be disposed of in an appropriate landfill. Implementation of these measures would reduce the impact of excess rock being brought to the surface to a less-than-significant level.

Mineral Resources

Project activities would not affect the extraction of mineral resources because no new areas of disturbance are anticipated.

Impact GEO-1: Seismic-Induced Damage

Seismic motion could damage the pipeline. (Potentially Significant, Class II)

Seismic displacement and ground cracking could damage the pipe in the vicinity of the Garlock and Calico Faults. The wall thickness has been adjusted for this concern, but damage could occur to the pipe. There has been no geohazard assessment of the Cadiz Lateral.

Mitigation for Impact GEO-1:

MM GEO-1a: ***Checking for Pipe Damage.*** *60 days prior to the start of operations as a natural gas transmission system, EPNG must have a Post Earthquake Inspection and Monitoring Plan approved by the CSLC. The plan must specify procedures to assess the integrity of the pipeline and its ability to meet the seismic design criteria used in fault crossings and other seismic hazards. The plan must include the following pipeline operations and maintenance procedures. Following an earthquake within the parameters shown in the table below, EPNG operations personnel would inspect all parts of the pipeline alignment that fall within the specified distance of the earthquake epicenter for evidence of permanent ground deformation (e.g., cracks or displacements). If surface fault rupture is reported or observed, the pipeline alignment within at least 1,000 feet of the rupture would be inspected. EPNG would submit reports of its findings to the BLM and the CSLC. Once approved, this plan must be included in EPNG's operation and maintenance program.*

Table 4.4-4. Earthquake Parameters

Earthquake Magnitude (Richter scale)	Epicentral Distance (miles)
6	5
6.5	10
7	15
7.5	20

MM GEO-1b*: Geohazard Assessment along Cadiz Lateral.* *60 Days prior to construction, EPNG must have a pipeline design approved by CSLC for the Cadiz Lateral. The design must be supported by a geohazard assessment and soil sampling equivalent to that conducted for Line 1903.*

Rationale for Mitigation

The mitigation measure ensures that seismic damage to the pipeline would be detected. Geohazards must be evaluated and mitigated prior to construction of the Cadiz Lateral. This process would mitigate any potential impacts due to seismic damage to less than significant.

Impact GEO-2: Exposure of Paleontological Resources

Construction activities could expose paleontological resources. (Potentially Significant, Class II)

Some construction locations have a high probability or are known to contain paleontological resources. On Federal lands, these include the sites listed in Table 4.4-3 and the Cadiz Lateral ROW. Direct impacts on these resources could result from grading and trenching; indirect impacts could result from erosion and unauthorized collection.

Mitigation for Impact GEO-2:

MM GEO-2. ***Avoidance or Scientific Excavation.*** *If avoidance of the resource is not feasible, scientific excavation to recover fossil materials would occur. No later than 60 days prior to construction, EPNG would prepare a Paleontological Resources Management Plan for review and approval by the CSLC and BLM. The plan must have the following elements:*

- *Conduct preconstruction, surveys of areas identified with high potential for paleontological resources. Those areas listed in Table 4.4-3 and the Cadiz Lateral ROW must be included, as well as areas off Federal lands with a high potential for paleontological resources.*
- *Prior to construction, conduct a Worker Education Program regarding procedures to minimize impacts on paleontological resources.*
- *During construction, conduct monitoring for those areas that have been previously identified as containing scientifically significant fossils on Federal lands, and areas off Federal lands with a high potential for scientifically significant fossils. A monitor approved by the BLM and CSLC would be present during ground-disturbing activities in these areas. The disturbed area would be checked prior to completion of the site activity. The monitor would have the authority to temporarily divert construction activity if significant fossils are found. The approved paleontologist would also be notified if a fossil is found in a non-monitored area.*
- *Identify recovered fossils and preserve them for curation at a museum, and prepare a final report of findings.*

Rationale for Mitigation

This measure ensures that paleontological resources known or suspected in construction areas would be protected from damage or loss through either avoidance or scientific excavation. Potential impacts to paleontological resources would, therefore, be less than significant.

Table 4.4-5 presents a summary of impacts on geology and soils and recommended mitigation measures.

Table 4.4-5. Summary of Impacts and Mitigation Measures for Geology and Soils

Impact	Mitigation Measure
GEO-1: Seismic-Induced Damage	**GEO-1a.** Checking for Pipe Damage **GEO-1b.** Geohazard Assessment along Cadiz Lateral
GEO-2: Exposure of Paleontological Resources	**GEO-2.** Avoidance or Scientific Excavation

4.4.5 Cumulative Impacts

In addition to the proposed Project, other projects may contribute to cumulative impacts on geologic and soil resources in the vicinity of the Project. The projects potentially contributing to cumulative impacts are discussed in Section 5.5, Summary of Cumulative Impacts.

The proposed Project is expected to result in only temporary impacts on near-surface geology and soils. The Project is also not expected to induce or aggravate landslides or seismic activity in the region. Because any Project impacts related to geology or soils would be highly localized and primarily limited to the time of construction, cumulative impacts on geology and soils would occur only if another project is planned for construction at the same time and place as the El Paso 1903 Pipeline Conversion Project. None of the projects listed in Section 5.5, Summary of Cumulative Impacts, meet this condition; consequently, cumulative impacts on geologic and soil resources would be less than significant.

4.4.6 Alternatives

No Project Alternative

The No Project Alternative would not convert the former All American crude oil pipeline system to a natural gas transmission system. This alternative would not affect geology and soils.

Ehrenberg to Daggett Alternative

The Ehrenberg to Daggett Alternative would not convert the portion of Line 1903 from MP 0 to MP 132.1. This alternative would avoid crossing the Garlock Fault, White Wolf Fault, and other small faults. The remaining impacts on geology and soils under the Ehrenberg to Daggett Alternative would be the same as described for the proposed Project.

Ehrenberg to Cadiz Alternative

The Ehrenberg to Cadiz Alternative would not convert the portion of Line 1903 from MP 0 to MP 215.75. This alternative would avoid crossing the Garlock Fault, White Wolf Fault, Calico Fault, and other small faults. The remaining impacts on geology and soils under the Ehrenberg to Cadiz Alternative would be the same as described for the proposed Project.

4.4.7 References

AMEC Earth and Environmental, Inc. 2003. Foundation Soil Information. Proposed Meter Stations and Pigging Facilities El Paso Line 1903 Pipeline. Kern and San Bernardino Counties, California. September 16, 2003.

AMEC Earth and Environmental, Inc. 2003. Conceptual Design for Mitigation of Fault Rupture Hazards El Paso Line 1903 Calico and Garlock Fault Crossings. San Bernardino and Kern Counties, California. June 5, 2003.

AMEC Earth and Environmental, Inc. 2002. Geohazard Assessment Addressing California State Lands Commission Concerns El Paso Natural Gas Company's Line Number 1903 Pipeline Conversion Project. Southern Great Valley and Mojave Desert, California. October 7, 2002.

Bedinger, M. S., K. A. Sargent, W. H. Langer. 1989. Studies of Geology and Hydrology in the Basin and Range Province, Southwestern United States, For Isolation of High-Level Radioactive Waste—Characterization of the Sonoran Region, California. US Geological Survey Professional Paper 1370E.

Bertoldi, L. B., R. H. Johnson, K. D. Evenson. 1991. Groundwater in the Central Valley, California—A Summary Report. US Geological Survey Professional Paper 1401-A.

Bishop, C. C. (compiler). 1963. Needles Sheet, Geologic Map of California, fourth printing 1992.

Blodgett, J. C. and J. S. Williams. 1990. Land Subsidence Problems Affecting Land Use at Edwards Air Force Base and Vicinity. US Geological Survey Water-Resources Investigations Report 92-4035.

Bortugno, E. J. and T. E. Spittler. 1986. Geologic Map of the San Bernardino Quadrangle, California, revised 1998.

Buwalda, J. P. and P. St. Amand. 1955. Geological Effects of the Arvin-Tehachpi Earthquake: in Earthquakes in Kern County, California Division of Mines Bulletin 171; G. B. Oakeshott, ed.

California Department of Conservation (CDC), Division of Mines and Geology. 1997. Guidelines for Evaluating and Mitigating Seismic Hazards in California. Special Publication 117.

California Division of Mines and Geology (CDMG). 1976. Earthquake Fault Zone Map of Monolith Quadrangle.

California Division of Mines and Geology (CDMG). 1988. Earthquake Fault Zone Map of the Kramer Hills Quadrangle.

California Division of Mines and Geology (CDMG). 1995a. Earthquake Fault Zone Map of the Newberry Springs Quadrangle.

California Division of Mines and Geology (CDMG). 1995b. Earthquake Fault Zone Map of the Troy Lake Quadrangle.

California Division of Mines and Geology (CDMG). 2000. Probabilistic Seismic Hazards, Peak Ground Acceleration Atlas. Web pages: www.consrv.ca.gov/dmg/rghm/psha/atlas.

California Division of Oil, Gas, and Geothermal Resources. 2000. Oil and Gas Fields Map of the District 4 Bakersfield Area. Web page: ftp://ftp.consrv.ca.gov/pub/oil/maps/dist4/Dist4_fields.pdf

California State Lands Commission and Bureau of Land Management. 1984. Proposed Celeron/All American and Getty Pipeline Projects, Draft Environmental Impact Report/Draft Environmental Impact Statement.

California State Lands Commission and Federal Energy Regulatory Commission. 2000. Questar Southern Trails Pipeline Company. Southern Trails Pipeline Project, Final Environmental Impact Statement/Environmental Impact Report. CSLC EIR No. 696; FERC/EIS-127D. July 2000.

California State Lands Commission and Federal Energy Regulatory Commission. 2002. Kern River 2003 Expansion Project, Final Environmental Impact Statement/Environmental Impact Report Volume I. CSLC EIR No. 710; FERC/EIS-0144. June 2002.

D. G. Honegger Consultants. 2002. Analytic Assessment of Seismic Hazards.

Davies, T. W., Jr., J. H. Simpson, G. C. Ohlmacher, W. S. Kirk, E. G. Newton. 1976. Map Showing Engineering Aspects of Karst in the United States. US Geological Survey Open File Report 76-623.

Dibblee, T. W., Jr. 1966. Geologic Map of the Lavic Lake Quadrangle San Bernardino, California. Miscellaneous Geological Investigations Map 1-472.

Dibblee, T. W., Jr. 1967. Areal Geology of the Western Mojave Desert. US Geological Survey Professional Paper 522.

Dibblee, T. W., Jr. 1970. Geologic Map of the Daggett [15'] Quadrangle. US Geological Survey Miscellaneous Geologic Investigations Map I-592.

Dibblee, T. W., Jr. and A. M. Bassett. 1966a. Geologic Map of the Newberry Quadrangle San Bernardino, California. US Geological Survey Miscellaneous Geologic Investigations Map I-461.

Dibblee, T. W., Jr. and A. M. Bassett. 1966b. Geologic Map of the Cady Mountains Quadrangle San Bernardino, California. US Geological Survey Miscellaneous Geologic Investigations Map I-467.

Dibblee, T. W., Jr. and G. P. Louke. 1970. Geologic Map of the Tehachapi Quadrangle Kern County, California. US Geological Survey Miscellaneous Geologic Investigations Map I-607.

Dibblee, T. W. and A. H. Warne. 1970. Geologic Map of the Cummings Mountain Quadrangle. US Geological Survey Miscellaneous Geologic Investigations Map I-611.

Earthquake Consultants International. 2002. Seismic Hazards Evaluation and Mitigation Plan for the El Paso Pipeline Nos. 1903 and 1904, between Wheeler Ridge, California, and the California – Nevada [SIC] State Line: Report prepared by ECI for ENSR Corporation February 25, 2002.

Environmental Systems Research Institute. 2001. Internet website for determining availability of Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps: http://mapserver2.esri.com/cgi-bin/hazard.adol. Revised February 8, 2001.

Federal Emergency Management Agency (FEMA). 1995. Flood Insurance Rate Maps for Kern County (Unincorporated Areas), Map No. 060075-2075, various panels.

Federal Emergency Management Agency (FEMA). 1997. Flood Insurance Rate Maps for San Bernardino County, California and Incorporated Areas, Map No. 06071C0000, various panels.

Hart, E. W. and W. A. Bryant. 1997. Fault Rupture Hazard Zones in California. CDMG Special Publication No. 42. Sacramento, CA.

Hart, E. W., W. A. Bryant, J. E. Kahle, M. W. Manson, and E. J. Bortugno. 1987. Summary Report: Fault Evaluation Program, 1986-1987 Mojave Desert Region and Other Areas. CDMG Open-File Report 88-1.

Hill, M. L. 1955. Nature of Movements on Active Faults in Southern California: in Earthquakes in Kern County, California Division of Mines Bulletin 171; G. B. Oakeshott, ed.

International Conference of Building Officials. 1991. Uniform Building Code.

Jennings, C. W. (compiler). 1967. Salton Sea Sheet, Geologic Map of California, fifth printing 1992.

McDonough, P. W. 1995 (ed). Seismic Design Guide for Natural Gas Distributors. American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering; Monograph No. 9, August 1995.

Norris, R. M. and R. W. Webb. 1990. Geology of California, second edition; John Wiley and Sons, New York, 541p.

Oakeshott, G. B. (ed). 1955. Earthquakes in Kern County, California During 1952. CDMG Bulletin 171.

O'Rourke, M. J. and Shinozuka. 1995. Mitigation of Damage to Lifelines, Gas and Liquid Fuel Systems: in Critical Issues and State-of-the-Art in Lifeline Earthquake Engineering, A. J. Schiff and I. G. Buckle, eds. American Society of Civil Engineers, Technical Council on Earthquake Engineering Monograph No. 7, October 1995.

O'Rourke, M. J. and X. Liu. 1999. Response of Buried Pipelines to Earthquake Effects. Multidisciplinary Center for Earthquake Research, Research Foundation of the State University of New York, 249 p.

Pelmulder, S. D. 1995. Seismic Hazards: in Seismic Design Guide for Natural Gas Distributors; P. McDonough editor; American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering; Monograph No. 9, August 1995.

Perry, O. W. 1955. Highway Damage Resulting form the Kern County Earthquakes with supplemental Bridge Earthquake Report by S. Mitchell: in Earthquakes in Kern County, California Division of Mines Bulletin 171; G. B. Oakeshott, ed.

Radbruch-Hall, D. H., R. B. Colton, W. E. Davies, I. Lucchitta, B. A. Skipp, and D. J. Varnes. 1982. Landslide Overview Map of the United States. US Geological Survey Professional Paper 1183.

Reynolds, R.E. 1988. Paleontologic Monitoring and Salvage for Federal Lands along the All American and Celeron Pipeline Project. San Bernardino County Museum.

Ross, D. C. 1989. The Metamorphic and Plutonic Rocks of the Southernmost Sierra Nevada, California, and Their Tectonic Framework. US Geological Survey Professional Paper 1381.

San Bernardino County Museum. 2000. Web page: www.co.san-bernardino.ca.us/museum/ geosci.htm.

San Bernardino County Museum. 1988. Paleontologic Monitoring and Salvage Federal Lands along the All American and Celeron Pipeline Project, California Section, Part 1. Robert E. Reynolds, Curator, Earth Sciences. August 1988.

Southern California Earthquake Data Center (SCEDC). 2000. Internet site: www.scecdc.scec.org/ mojfault.

Southern California Earthquake Data Center (SCEDC). 2001. Recent Earthquakes in California and Nevada. Internet site: www.scedc.scec.org:3128/recenteqs/Quakes/ci09175289.html.

US Geological Survey. 2000. The October 16, 1999 M7.1 Magnitude Hector Mine Earthquake. Web page at http://pasadena.wr.usgs.gov/hector.html.

Wills, C. J. 1996. Liquefaction in the California Desert. California Geology, California Division of Mines and Geology, March-April, 1996. Report accessed from website http://www.consrv.ca.gov/ dmg/pubs/cg/1996/96cgbarn.htm.